Title: Jacketed Ammunition

Field of the Invention:

[001] This invention relates to spin stabilized projectiles fired from rifled gun barrels, and particularly to small arms ammunition.

Background to the Invention:

[002] Historically, small calibre projectiles have been made from lead alloys or contained lead cores. Lead is an easy metal to form due to its' ease of malleability (very low Young's modulus) and projectile cores of this material readily deform under the high engraving stresses associated with a projectile being fired from a rifled gun barrel. Both of these material properties provide advantages for projectile design and permit good accuracy performance and low gun barrel wear.

[003] However, in order to mitigate the barrel fouling associated with 1-piece, all-lead projectiles, copper-zinc alloy, (also known as gilding metal) jackets were introduced. These projectile jackets are thin enough in profile and ductile enough to deform adequately under the engraving stresses and transfer the spin from the rifling and still retain projectile integrity when the projectile leaves the muzzle of the gun. These 2-piece projectiles are still in production today, mainly for hunting and some military applications.

[004] Further advances to projectile design have resulted in copper jacket projectiles with a short, conical hardened steel penetrator in the tip of the projectile and a cylindrical lead core at the aft of the projectile. Antimony is often added to the core for increased mechanical strength. The jacket allows the integration of the two (penetrator and core elements) to reach the target together and provide as well the desired interior ballistic performance. This style of three-piece projectile is commonly referred to as "ball" ammunition. This design has improved terminal ballistic effects over all-lead core projectiles and allows increased penetration of hard targets due to the addition of the very hard penetrator while still permitting good accuracy and acceptable barrel wear due to the lead/antimony alloy core.

[005] All NATO 5.56mm and most common small calibre infantry weapons in service today currently feature such two-piece core projectiles due to the relative ease of manufacture, low production cost, reliability of performance and high lethality upon impact in the human body. Although the penetration performance of ball projectiles is superior in metal plates and other hard targets, performance is sometimes marginal when firing on the NATO standard steel plate targets during production lot acceptance testing in cold weather conditions. Thus, the current design is at its design limits for penetration.

[006] In recent times, lead has been shown to be a highly toxic substance and has been banned from use in gasoline and paints, to name but two commercial products previously containing lead. In addition, many tons of lead have been entering the water system every year through the simple loss of lead fishing sinkers and these too have been prohibited in many localities due to the toxic effect on the environment and the food chain. As well, the manufacturing process may expose persons working in the environs of the projectile production equipment to lead and/or lead dust which is harmful to the health.

[007] Now the same health concerns are leading government agencies around the world to mandate the elimination of lead from the production of small calibre ammunition. This trend applies to commercial as well as military products, but numerous technical challenges have delayed this thrust for military products. One of the objectives of the elimination of lead is to reduce airborne contaminants in the shooter's breathing zone.

[008] The first challenge is to find a suitable replacement material for lead. Lead is an inexpensive and extremely soft, easily formed metal, almost ideal for manufacturing purposes.

[009] Lead is also a high-density material, which is a great advantage to the ballistician. A heavier projectile for a given shape will travel farther and retain its velocity better at longer ranges.

[0010] The objective of any infantry fighter is to incapacitate the enemy and this is most often achieved by the transfer of kinetic energy to the target. So, a heavier

projectile will transfer more energy to a given target than a lighter version for impacts with the same terminal impact velocity.

[0011] Clearly, any lead-free projectile should ideally have the same muzzle velocity and mass as the steel and lead containing ball projectile it seeks to replace. The other obvious advantage of having a lead-free projectile of nearly identical mass relates to the requirement of retaining the same exterior ballistic performance. Otherwise all current weapon sighting systems would require replacement, re-working or extensive re-adjustment and existing ballistic firing tables would no longer be valid. This would place an unacceptable logistical burden on most military forces of any significant size in the world.

[0012] It has not been a simple matter to replace lead as a material for making projectiles. Alternative projectiles considered in the past have not been able to maintain the mechanical and physical properties of lead so as to achieve comparable exterior ballistic performance. For example, the ability of the projectile to retain its velocity and energy is measured by its sectional density and is proportional to the projectile mass divided by the square of the calibre. Thus, it is seen that a projectile of lower mass or density will not retain its velocity and energy as well as a projectile of higher mass and energy. This leads one to conclude that a projectile comprised of a lower density material should be longer to retain the same mass as a lead filled projectile.

[0013] Recent efforts to replace lead in projectiles have focused on high density powdered metals, such as tungsten with polymeric or metallic binders. However, these replacement materials have yet to meet all desired specifications and performance goals for stability, accuracy and economy of manufacture.

[0014] Many different materials and combinations of materials have been considered as replacements for the lead core in the manufacture of non-toxic projectiles. See U.S. Patent 6,085,661 in which copper is used as a replacement for lead.

[0015] Another solution being explored is the replacement of lead with other high density metals such as bismuth. Bismuth metal possesses material properties similar to those of lead. Shotgun ammunition that utilizes bismuth shot is also

commercially available, but the density of this metal is still only 86% of that of lead (9.8 versus 11.4 g/cm3), and again this creates concerns with regards to exterior ballistic performance. Two other problems with bismuth are the high cost of the raw material and the relative scarcity of supply in the world.

[0016] In pelletized projectiles, such as shotgun shot, lead has been used for many years for hunting waterfowl and other game birds. Where lead shot has been banned, steel shot has also been sometimes used. However, due to the high hardness and much lower density (7.5 versus 11.4 g/cm3), steels are less desirable choices for use as projectile materials due to the reduced terminal ballistic effect and increased barrel wear.

[0017] The manufacturers of steel pellet shot shells recommend using a steel shot at least two sizes larger in diameter than lead for the same target and similar distances. This further diminishes effectiveness by decreasing pattern density (the number of pellets per shot), thus reducing the probability of hit on a moving target. Although ammunition manufacturers are developing new and improved additives for use with steel shot, the ammunition appears to cause excessive wear and undue damage to many shotgun barrels.

[0018] Tungsten and bismuth are two high-density materials that have been attempted in alloy form with varying degrees of success in various commercial and military projectile designs (Reference 2 refer to bismuth patents for shot shell pellets or similar here). High-density depleted uranium and tungsten alloys have both been used for long rod kinetic energy penetrators for tank ammunition. Tungsten-nylon and tungsten-tin are two well-known combinations (Reference 3 refer to US patents here) that rely on advanced powder metallurgy techniques to achieve the desired form of a one-piece projectile core for small calibre projectiles.

[0019] The objective of the jacketed tungsten-nylon or tungsten-tin powder metallurgy one-piece core projectile designs is to create a new material with an actual density equivalent to the hybrid density of the steel and lead components they replace, in order to maintain the volume the two parts occupy. This new single piece would fit inside a copper projectile jacket. as a “drop-in” replacement part

and has the advantage of not requiring any changes whatsoever to existing high cadence projectile manufacturing or cartridge assembly machinery.

[0020] One disadvantage with these powder metallurgy concepts is that the process does not lend itself well to the manufacture of components that have to fit inside of another part and retain very close tolerances. Part of the reason for this problem is due to the irregular shrinkage associated with the sintering process that is often required of these powder metallurgy parts to achieve optimal density.

[0021] Normally, this tolerance problem can only be overcome by performing post-manufacturing operations on the sintered part, like grinding. Obviously this increases cost and reduces production cadence, which is not desirable.

[0022] In addition, tungsten is also costly to obtain and in relatively scarce supply in the world which makes it considerably more expensive to manufacture and subject to price volatility. There are also potential procurement obstacles in the event of extended armed or economic conflicts involving the nations possessing this strategic element (or their neighbours) if either were unfriendly or unsympathetic during any such conflict.

[0023] Clearly, any replacement material for lead should be as abundant as possible to ensure a secure supply of raw materials and be as economical as possible to produce since infantry projectiles are practically considered a commodity nowadays. The replacement component should preferably be made of a single piece to reduce manufacturing and projectile assembly costs. Finally, the manufacturing process of the new core material should not require any post-manufacturing processes to ensure the current high production rate and capacity on existing projectile assembly equipment.

[0024] It is clear from the above that several attempts have been made in the past to obviate or diminish the use of lead as a primary material for making projectile cores. Yet, no one heretofore has achieved satisfactory performance from non-lead materials.

[0025] This reduces the field of material contenders considerably and forces one to conclude that in fact a one-piece, all-steel core could be a serious contender if certain major technical challenges can be resolved.

[0026] A great advantage of the one-piece steel core projectile is increased penetration performance in hard targets. Since the mass of the lead core has been replaced by an equivalent mass of steel, the penetration of the NATO standard steel plates is easily accomplished and at even greater ranges. This resolves the marginal penetration performance problem associated with conventional ball projectiles.

Problem 1 of new projectile

[0027] The main drawback with a hard, one-piece steel core projectile interior is that suddenly the projectile engraving forces are dramatically increased and the mechanical stresses generated will induce premature gun barrel wear through the enormous friction forces generated.

[0028] The contact surface of the projectile is called the "driving band". This is the area of the projectile that is in direct contact with the rifling of the weapon and undergoes plastic deformation when fired through a gun barrel. In conventional ball projectiles, the lead core under the copper jacket is in the position of the driving band. The soft copper jacket and malleable lead core are ideal materials for a driving band since they are readily plastically deformed and lengthen longitudinally under axial compression in accordance with Poisson's ratio for these metals.

[0029] It must be recalled that the process of firing a conventional spin stabilized projectile down a gun barrel requires extruding an oversized cylinder down an undersized tube. The tube has grooves with a helical twist and causes the cylinder to rotate inside the barrel, thus ensuring stability during flight. This is the principle of the spin-stabilized projectile and is sensitive to the length to diameter ratio of the projectile.

[0030] The stresses on today's modern infantry small calibre projectiles are enormous due to the very high muzzle velocities and very fast spin rates involved. The current projectiles are on the limits of what is possible in mechanical design and production must be continuously monitored to ensure quality and performance. In some cases, the metal forming processes involved in manufacturing the copper projectile jacket induce residual stresses that may slightly weaken the projectile.

Problem 1 of old projectile

[0031] This is usually a manageable issue with lead-containing projectiles since the lead is so soft it deforms quite readily and friction forces are normally manageable. However, the high engraving stresses on current small calibre infantry projectiles may occasionally cause "projectile stripping" due to excessive shear forces acting on the jacket at the annular contact surface at the rearward end of the short steel penetrator. Projectile stripping occurs when the local shear stresses exceed the ultimate strength of the projectile jacket material and the projectile breaks up upon muzzle exit.

[0032] If projectile stripping occurs, the projectile loses integrity upon exiting the muzzle, is no longer a controlled projectile and immediately becomes a critical safety hazard since its trajectory is unknown. The result of stripping is separation of the copper projectile jacket, lead core and steel penetrator in flight which is highly undesirable as it can lead to lethal accidents for friendly forces training or fighting nearby.

[0033] Projectile stripping has been known to occur when the diameter of the rearward conical section of the short steel penetrator exceeds that of the forward cylindrical section of the lead core. The effect is one of a generating a sharp cutting edge on the inside of the copper jacket, magnified during the projectile engraving process.

Problem 2 of old projectile

[0034] One possible solution to the problem of projectile stripping is to perform a post-production annealing of the projectiles. This heat treatment acts to relieve some of the residual stresses induced in the copper jacket during fabrication. This solution however creates other problems, as there is a negative effect on the penetration performance since the annealing process reduces the hardness of the short steel penetrator and reduces penetration performance in the NATO steel plate targets, especially at lower temperatures.

2 advantages of new projectile – solving problems 1 & 2 of old projectile

[0035] Stripping is not a concern for the one-piece, all-steel core projectile since there is no longer an internal interface to worry about, but it does generate other problems, since the hard steel core does not readily deform and causes greatly increased friction as the projectile travels down the bore which in turn creates excessive heating of the gun barrel. Therefore annealing is not required with the one-piece, all-steel core projectile, so penetration in hard targets is improved, even at lower temperatures.

Problem 1 of new projectile

[0036] Excessive friction heating due to the one-piece, all-steel core projectile may lead to accelerated mechanical wear of the interior surface of the gun barrel (and gun barrel lining if one is present) that unacceptably shortens the service life of the weapon. The cause is localized surface melting of the copper projectile jacket inside the gun barrel which causes a build-up of jacket material where barrel heating is highest. This phenomenon is known as "coppering" and must be resolved by reducing friction forces within the barrel.

[0037] Many modern infantry assault weapons have a metallic lining inside the gun barrel to extend barrel life. Typically chromium is chosen for its excellent hardness and resistance to mechanical wear. Chromium has the additional advantage of providing a smooth surface for the travel of copper-jacketed projectiles since copper is not soluble in chromium. Chromium is soluble in steel however, due to the atomic affinity of copper and iron, so if mechanical friction increases to such a level that the chromium gun barrel coating is compromised, coppering will begin to occur rapidly on the exposed steel surface.

Problem 2 of new projectile

[0038] Once coppering starts to occur, the resulting build-up causes the interior diameters of the rifle lands and grooves to decrease at the exposed surfaces and now the projectile has to pass through restricted zones that induce even more localized stress. This problem will continue to worsen as more projectiles are fired through the gun barrel unless the barrel is thoroughly cleaned with a "de-coppering" agent. Coppering often results in a disruption of proper projectile spin or even complete

loss of projectile integrity, either inside the barrel or upon exiting the muzzle of the weapon. This additional instability or "projectile yaw" in flight due to barrel coppering also leads to greatly increased impact dispersion on the target with a reduction of accuracy and reduced probability of hitting the target that is unacceptable to the shooter.

<u>Problem 3 of old projectile</u>

[0039] Another well-known disadvantage with conventional ball ammunition is its tendency to fragment into many pieces upon impact with a ballistic gelatine target. Ballistic gelatine is a material commonly used as a simulation for human tissue to establish terminal ballistic performance. The requirement for a non-fragmenting projectile stems from Hague convention IV of 1907, which forbade projectiles or materials calculated to cause unnecessary suffering to the opposing soldiers on the battlefield. An example of a prohibited projectile is the now infamous Dum-Dum projectile which was judged to cause excessive suffering.

[0040] Projectile fragmentation in the human tissue is the result of overly rapid transfer of kinetic energy from the projectile to the target and the resulting excessive bending moment acting on the already stressed projectile. As the projectile leaves the air and enters a much higher density medium, such as human tissue, its stability is immediately compromised and it begins to tumble rapidly. This is a good means of transferring kinetic energy to the target, but is considered as causing excessive injury to the opponent if the tumbling projectile does not remain intact, as is often the case with the conventional three-piece projectile (ball) ammunition.

[0041] Since the interior of the conventional ball projectile comprises one steel and one lead component, the projectile normally bends at this steel/lead interface and shears the copper alloy jacket there. This interface acts as a hinge that bends until it breaks and then allows the lead to disperse in human tissue as tiny fragments that are very difficult to remove from the soldier after the battle. Some countries are in the process of considering restricting or eliminating the use of such fragmenting projectiles of use by their infantry soldiers, but to date no reliable solution has been identified

Advantage of new projectile – solution to problem 3 of old projectile

[0042] A jacketed, one-piece steel core projectile is not sensitive to high bending moments, since there is no "hinge" upon which the bending moment may act. As a one-piece steel core projectile tumbles in tissue, it remains intact and thus does not violate the Geneva or Hague conventions since it is relatively easy to locate and remove after the battle. It also does a good job of transferring energy quickly and incapacitating the opponent in a more humane manner since the longer projectile will commence tumbling faster without breaking into numerous small fragments.

[0043] An obvious means of reducing friction forces in an all-steel core projectile and thereby reducing coppering and stripping is by simply reducing the projectile diameter.

[0044] However, other potential problems may be encountered with the performance of spin-stabilized small calibre projectiles related to a decreased projectile diameter.

Problem 3 of new projectile

[0045] If proper projectile spin transfer from the rifling is disrupted, it is also evidenced by projectile impacts on the paper target that exhibit evidence of "keyholing" or impact at a noticeable angle of yaw. This is highly undesirable behaviour for small arms ammunition since in reality, penetration of hard targets is thus reduced because the projectile is no longer travelling in a straight line through the target material.

Problem 4 of new projectile

[0046] If the projectile fails to spin properly inside the rifling of the gun barrel, it may exhibit balloting (uncontrolled yawing motion inside the barrel) and damage the barrel lands and grooves. Once this happens, the gun barrel is no longer serviceable and must be replaced since accuracy is degraded and jacket stripping may occur.

[0047] Many of these above problems can arise from the choice of steel or any other hard material as a one-piece replacement for the existing conventional ball core components.

Problem 5 of new projectile

[0048] Properly closing the base of a conventional lead core ball projectile is not a complex affair, since the lead is easily formed and readily adheres to the final form imparted onto it by the copper jacket during the projectile closing operation. This is much more difficult with an all-steel core, since it cannot be deformed during the closing operation.

Problem 6 of new projectile

[0049] Another design challenge due to the choice of an all-steel core component is the increased weapon chamber pressure generated during firing of the cartridge. Maximum chamber pressure values are strictly regulated in commercial and military ammunition for obvious safety reasons. If ammunition chamber pressures generated exceed prescribed limits during firing, catastrophic barrel failure may result as a worst case, or in the best case, the repeated high pressure cycles will contribute to accelerated fatigue of the metal parts and premature wear of the weapon.

[0050] The challenges of achieving maximum muzzle velocity while maintaining acceptable chamber pressures are well understood in conventional ball ammunition. The increased pressure experienced with all-steel core projectiles is directly related to the increased rifling engraving stresses described above.

[0051] Again, the obvious means of reducing weapon chamber pressure and projectile engraving stresses is by simply reducing the exterior diameter of the projectile. This is true of conventional as well as all-steel core projectiles, but generates a proportional reduction in accuracy on target, since projectile engraving and thus uniformity of projectile spin is reduced. If the projectile diameter is reduced beyond a given point, projectile balloting may occur. Clearly, simple projectile diameter reduction is not an acceptable solution to eliminate high chamber pressure, excessive projectile stress or barrel wear.

[0052] The invention in its general form will first be described, and then its implementation in terms of specific embodiments will be detailed with reference to the drawings following hereafter. These embodiments are intended to demonstrate the principle of the invention, and the manner of its implementation. The invention

in its broadest and more specific forms will then be further described, and defined, in each of the individual claims which conclude this Specification.

Summary of the Invention:

[0053] Clearly, a one-piece all-steel core needs to be longer than the conventional steel penetrator and lead core it replaces since steel is considerably lower in density than lead. It is essential to achieve the same projectile mass to retain the required level of muzzle kinetic energy for equivalent terminal ballistic performance on the target.

[0054] Upon further examination and analysis, it is learned that a longer, one-piece all-steel core, copper jacketed projectile can be made to nearly match the weight of the conventional projectile if it is extended in length to approximately the same length as a conventional tracer projectile. This means that such a new projectile design could still be produced and assembled on existing projectile manufacturing equipment and assembled into complete cartridges using existing cartridge assembly equipment without requiring significant or expensive tooling modifications. Thus, the length over diameter ratio, or L/D must be greater for a steel core projectile than for a conventional lead core ball projectile in order to retain the same projectile mass.

[0055] The use of a longer projectile, like the tracer or steel core projectile requires a greater seating depth of the projectile into the cartridge case, since the overall cartridge length must be respected at all times. The cartridge case cannot be crimped onto the projectile at a lower position either without affecting overall cartridge length, so this leads to reduced ullage or less empty space between the projectile base and the surface of the propellant bed.

Brief Description of the Drawings

[0056] Figure 1 shows an image of all lead projectile which has no jacket like .22

[0057] Figure 2 shows an image of an M193 type projectile.

[0058] Figure 3 shows an image of an SS109 type projectile.

[0059] Figure 4 is the same as Figure 3, but different hatching for different core materials.

[0060] Figure 5 shows an image of a longer C78 tracer projectile.

[0061] Figure 6 shows an image of solid cylinder under axial compression and how it gets longer.

[0062] Figure 7 shows an image of the penetrator and core with stresses acting on the jacket.

[0063] Figure 8 shows an image of a dum-dum projectile.

[0064] Figure 9 shows an image of broken projectile therein, (refer to DREV report).

[0065] Figure 10 shows an image of the IP core design.

[0066] Figure 11 shows an image of the IP projectile.

[0067] Figure 11A is a side section view of a solid core projectile.

[0068] Figure 12 is a partial side section view of an all-steel core projectile with the various portions of the core in evidence.

[0069] Figure 12A is a side section view of an all-steel core projectile with the various portions of the core in evidence.

[0070] Figure 13 is a more detailed sketch showing one embodiment of the geometry of the steel core in the projectile jacket.

[0071] Figure 14 is a sketch illustrating the gap present between the projectile core and jacket.

Description of the Preferred Embodiment

[0072] This invention relates to non-toxic, improved performance, small calibre all-steel core jacketed projectiles in general, particularly those up to 12.7mm calibre.

[0073] Non-toxic projectiles do not contain lead, a soft metal. Replacing lead presents many manufacturing and performance-related challenges, like excessive gun barrel wear.

[0074] According to the invention, the design of the all-steel core must be made in such a way that the accuracy, chamber pressure and projectile engraving forces are similar to those found in conventional lead core ball projectiles in order to meet

barrel wear performance requirements. The choice of steel as a core material is also important in maintaining a cost efficient projectile while increasing penetration of hard targets.

[0075] One embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, of which:

[0076] Referring to the drawings, an all-steel core projectile is made of a copper alloy or gilding metal jacket 11 and an all-steel core 12.

[0077] A frusto-conical portion of the all-steel core, 14 extends rearwardly from the ogival front end 15, the frusto-conical portion having a small angle of approximately 0.85°, whereby the junction of the ogival front end and the frusto-conical portion provides a relatively smooth blended junction.

[0078] There is a gap between the projectile jacket 11, and the frusto-conical portion of the core 14, such that the two are not in continuous contact.

[0079] A short cylindrical section of the core, 16 extends rearwardly from the frusto-conical portion of the core and serves as the principle driving band.

[0080] Rearwardly of the short cylindrical section 16, is a short rearwardly tapering end section, 13 with a conical angle of approximately 83°.

[0081] It is therefore the object of the invention to provide a jacketed, non-toxic projectile which:

1. contains no lead or heavy metals;
2. has a one-piece steel core;
3. the core is made of a hardened (approx. 0.4% carbon) steel for improved penetration performance in hard targets;
4. meets industrial and military specification requirements for gun barrel wear;
5. chamber pressure;
6. accuracy;
7. projectile integrity;
8. stability in flight; and
9. will not fragment upon impact in ballistic gelatine, even at very short ranges;

10. has a thicker copper alloy jacket than standard ball rounds.

[0082] According to the invention, the forward portion of the all-steel core has an ogival shaped front end followed by frusto-conical portion with a small conical angle, whereby the exterior surface of the frusto-conical portion of the core is not in continuous contact with the interior surface of the projectile jacket. The gap between the jacket and the core is filled with air. The frusto-conical section merges into a short cylindrical section, followed by a final tapered section that extends backwards from the rear end of the short cylindrical section.

[0083] The ogival section of the projectile is essential in facilitating projectile feeding from weapon magazines and/or belts. An ogive presents a smooth surface with no angles to get caught on weapon components during feeding to the chamber.

[0084] The projectile core is preferably made of hardened AISI 1038 steel, or other hard material with a Rockwell hardness of 45 or greater on the "C" scale to ensure improved penetration of hard targets.

[0085] The jacket of the projectile is preferably made of a ductile copper/zinc alloy or gilding metal containing approximately 90% copper and 10% zinc. The thickness of the jacket is also helpful in meeting the barrel wear criterion. The jacket thickness of the preferred embodiment is slightly thicker than conventional ball projectile jackets. A thicker copper alloy jacket requires no additional special coatings or other special treatment to reduce friction and acts as a friction reducing medium between the hard steel core and the gun barrel.

[0086] The projectile is assembled such that the jacket is in direct contact with the one-piece core on the ogival front end, the short cylindrical section and the rearwardly tapering end portion. There is a small air gap between the projectile jacket and the frusto-conical portion of the core.

[0087] The gap is generated due to the slight angle of the frusto-conical portion of the core. The angle of this section is preferably 0.85°, but may range between 0.7° and 1.0°. This gap allows the copper jacket material to flow plastically during engraving and compensate for the unyielding hard steel core underneath. The deformation of the jacket must be sufficient to maintain acceptable chamber pressure values, but not so great as to hinder the transfer of projectile spin and thus

stability. This narrow range of angle is very important to ensuring the accuracy of the projectile in flight, but is not the only factor involved.

[0088] The value of the angle of the frusto-conical portion of the core is critical since too large an angle will result in an undersized ogival front end and the projectile will not be properly supported in the barrel. This will lead to an increase in projectile yaw and reduced accuracy on the target.

[0089] If the angle of the frusto-conical portion of the core is too small, the gap will be too small, the cylindrical parallel portion will be too long and increase projectile engraving forces. The length of the cylindrical parallel portion must be much less than the length of the frusto-conical portion.

[0090] The ratio of the length of the short cylindrical section (driving band) of the core to the longer frusto-conical section is very important for maintaining stability of the projectile in flight. This ratio should be preferably less than 0.3, but may range between 0.3 and 0.1, with best results obtained at a ratio of 0.2. If the cylindrical parallel portion is too long, excessive chamber pressure and barrel wear will result. If this portion is too short, the projectile will slip in the gun barrel rifling and diminish in stability in flight, thus affecting accuracy.

[0091] The section of jacketed projectile that acts as the driving band (over the cylindrical parallel portion of the core) is in continuous contact with the rifling, while the frusto-conical section is only partially and progressively in contact with the rifling. This tapered gap between the jacket and the frusto-conical portion of the core is key to the invention, since it allows the projectile to have acceptable internal and external ballistic performance characteristics, with greatly enhanced terminal ballistic properties due to the hard steel core. The taper allows for gradual engraving to ensure acceptable stresses while maintaining good precision on the target. Other designs were tried, whereby the gap was cylindrical or other non-conical shapes and the target accuracy always suffered greatly.

[0092] As the jacketed projectile starts advancing down the barrel rifling from its starting position in the forcing cone of the rifling, it gradually and progressively engraves in the lands and grooves of the rifling. The exact initiation point of engraving occurs somewhere along the length of the frusto-conical section of the

core and is fully complete when it is in full contact with the short cylindrical section. This feature is very important since the various small calibre weapon platforms have different land and groove diameters, and can be found in various states of wear and in this way these differences can be accommodated.

[0093] If the gap were to be filled with another material, it would have to be inexpensive, easy to manufacture, very easily compressible and not have any deleterious affect on the projectile jacket during the compressive action of engraving. Otherwise it could potentially cause the jacket to rupture when it is being deformed through engraving. This could be a second, less cost-effective variant however.

[0094] Several tests were made during the development of this new projectile; involving various combinations of angles and lengths of the two main core portions. High chamber pressures (380 Mpa) were measured when the length of the cylindrical section was too long. This is over NATO specification limits and potentially dangerous. The final configuration resulted in pressures around 330 Mpa.

[0095] Several tests were also made to establish the optimal angle of the frusto-conical section. The first test resulted in a barrel that was worn beyond acceptable limits after only 2,000 rounds fired in approximately 90 minutes, as per NATO specifications. On the second try, after several months of design effort the angle was slightly increased and the length of the cylindrical section was reduced. This time the barrel only became excessively worn after 4,000 rounds fired.

[0096] On the third and successful attempt, the diameter of the steel core driving band and the length of the cylindrical section were slightly reduced and the projectile passed the NATO barrel wear performance requirements, even after 5,000 rounds were fired. When the diameter of the driving band portion of the steel core was further reduced, accuracy on target was greatly diminished.

[0097] These tests were performed over a couple of years.

[0098] Several accuracy tests were also performed over this period to evaluate the best angle and length of the two key core sections. The taper angle on the core is

essential to meeting accuracy requirements, since the projectile is progressively supported in the barrel as it advances down the rifling.

[0099] The radius at the junction of the rear face of the rearwardly tapering section (the boat tail section) must be sufficiently large to allow adequate mating of the copper alloy jacket over the base of the core. If the radius is too small, the jacket material does not adhere, or close properly. This may result in high pressure propellant gasses infiltrating between the two components (core and jacket) and cause projectile stripping the moment the projectile leaves the barrel and is no longer supported by the rifling of the gun barrel.

Conclusion

[00100] The foregoing has constituted a description of specific embodiments showing how the invention may be applied and put into use. These embodiments are only exemplary. The invention in its broadest, and more specific aspects, is further described and defined in the claims which now follow.